Aspects of the History and Fishery of the Murray Cod, *Maccullochella peeli* (Mitchell) (Percichthyidae)

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Aspects of the history and fishery of Australia's most famous and largest inland freshwater fish, the Murray cod, *Maccullochella peeli*, are briefly reviewed. Information and data on fossil records, the prominence of Murray cod in aboriginal mythology and culture, observations of cod by explorers and early settlers, and the development and subsequent decline of a commercial fishery are presented. Possible factors contributing to the reduced abundance of Murray cod are discussed. It is suggested that overfishing caused a decline between the late 1800's and the 1930's, but that extensive environmental modification of the Murray-Darling river system has adversely affected larval recruitment resulting in the dramatic decline in abundance of *M. peeli* since the 1950's.

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INTRODUCTION

The Murray cod, *Maccullochella peeli* (Mitchell, 1838) is an Australian, native, warmwater, percichthyid fish found naturally throughout most of the Murray-Darling river system (Fig. 1) with the exception of the headwaters of some tributaries in Victoria and southern New South Wales (Lake, 1971).

M. peeli is Australia's, and one of the world's largest freshwater fish. Whitley (1955) stated that Murray cod grow to 1.8 m (6 ft) and 83 kg (182 lb); however, a cod of 113.6 kg (250 lb) is reported to have been captured from the Barwon River near Walgett in 1902 (Noble, 1955). Although cod in excess of 50 kg are rarely captured, small numbers of cod between 20 and 40 kg are regularly taken by experienced commercial and recreational fishermen, particularly in the Darling, Barwon and Edward rivers, the lower reaches of the Murray and Murrumbidgee rivers, Lake Mulwala on the Murray River, and Lake Burrinjuck on the headwaters of the Murrumbidgee River. Because of its size and excellent edible qualities, Murray cod is highly valued by both commercial and recreational fishermen.

Despite its importance, there has been little research into the natural history of *M. peeli*. This paper briefly reviews the part played by Murray cod in aboriginal mythology and culture, the observations made of the species by explorers and early settlers, and the development, decline and current status of the Murray cod fisheries. Possible causes of the dramatic decline in abundance of Murray cod are discussed.

HISTORICAL ASPECTS OF MURRAY COD

Origin and Fossil Records

Most Australian freshwater fishes, including *M. peeli*, are considered to have a relatively recent marine ancestry (Whitley, 1959; Darlington, 1965). MacDonald (1978) suggested that the *Maccullochella* and *Macquaria* groups (both percichthyids) diverged from a common ancestor during a marine stage of their evolutionary development and made separate colonizations of Australian freshwaters.

Hills (1946) recorded fossil Murray cod from diatomaceous earth in the Warrum-

bungle Mountain areas and considered the remains to be not older than Pliocene (started 7 m.y.a.). However, Browne (1972) stated that the basalt overlaying these diatomaceous earths had been dated as Upper Miocene, and Taylor *et al.* (1980) reported Murray cod fossils from diatomite in the Cooma region to be of Miocene age (26-7 m.y.a.). The diatom flora associated with these fossils is of the type found with Lower Tertiary basalts (Gill, 1970) and so the ancestral *Maccullochella* may be up to 60-65 million years old. Hills (1946) stated that the former distribution of *M. peeli* (*M. macquariensis* as used by Hills, 1946, synonymous with *M. peeli*) in the western drainage, as determined by fossil records, was similar to the current distribution.

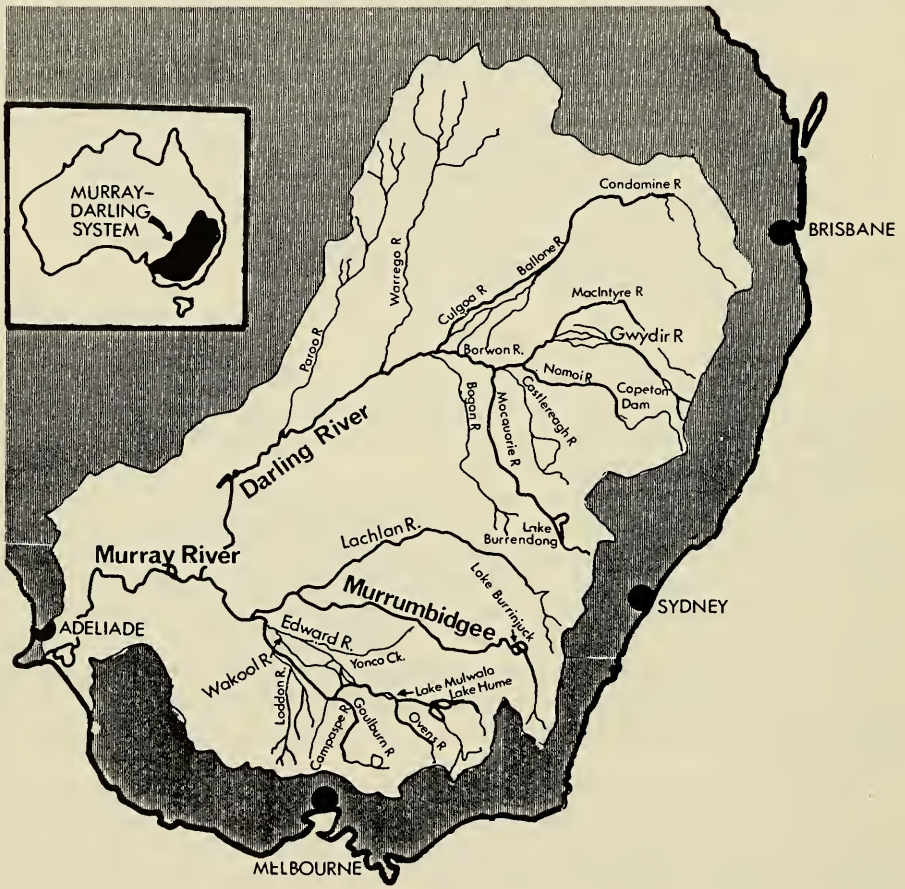

Fig. 1. The Murray-Darling river system.

Aboriginal Mythology and Culture

The Murray cod plays a prominent part in aboriginal mythology (Ramsay Smith, 1930; Berndt, 1940). According to legend, a huge fish, the Murray cod (called 'ponde' by the aborigines*) burst forth from the depths of the earth at the source of the Murray

* According to Ramsay Smith (1930) and Berndt (1940) the aborigines of the lower Murrumbidgee and Murray River regions called the Murray cod 'ponde', but Bennett (1834) states that aborigines in the Yass region on the upper Murrumbidgee River called the river cod 'mewuruk' and the aborigines in the Tumat [sic] country called the varieties of river cod 'bewuk' or 'mungee'.

River, which was then only a small stream of water trickling to the southern ocean. The Murray cod struggled along the narrow stream digging with its head and swinging its powerful tail making the river deep and forming all the bends. Then Nepelle, the Great Prophet, speared it at a site now known as Lake Alexandrina and with the help of the creative hero Ngurunderi, cut it into pieces and threw the fragments into the water, naming them 'tarki' (golden perch, *Macquaria ambigua*), 'tukkeri' (bony bream, *Nematolosa erebi*), 'tinuwarre' (silver perch, *Bidyanus bidyanus*) and all the other fishes of the system. When they had finished they threw the remainder back and said 'You keep on being ponde'.

Murray cod were a major food item of those tribes living adjacent to inland waters (Lawrence, 1971; Tindale, 1981) and as with all animal life, the aborigines made a detailed study of inland fishes, in particular the Murray cod which was considered *the* fish (Ramsay Smith, 1930). The aborigines were excellent fishermen and amazed early explorers and settlers with their prowess. They commonly used spears, nets and poisons to capture their prey, but also constructed different types of traps using brush fences, stones or hollow logs (Bennett, 1834; Lawrence, 1971; Tindale, 1951, 1981).

Explorers and Early Settlers

The inland explorers and early settlers were astounded by the abundance, size and delicacy of the Murray cod or as it was generally known by the pioneers 'River cod' or 'codfish'. The explorer John Oxley (1820) wrote of cod in the Lachlan River 'If however the country itself is poor, the river is rich in the most excellent fish, procurable in the utmost abundance. One man in less than an hour caught eighteen large fish, one of which was a curiosity from its immense size and the beauty of its colours . . . It weighed an entire 70 pounds, . . . Most of the other fish taken this evening weighed from fifteen to thirty pounds each'.

The holotype of *M. peeli*, which has since been lost (Berra and Weatherley, 1972), was collected from the Peel River, N.S.W., by the explorer Major Thomas Mitchell (Mitchell, 1838). There is an excellent drawing, dated 14th December, 1831, of a Murray cod in Major Mitchell's sketch book. Members of the expedition led by Charles Sturt down the Murrumbidgee and Murray rivers, caught and ate Murray cod (Sturt, 1899).

Bennett (1834) wrote that large quantities of the delicious 'River Cod' weighing up to 120 lbs were caught in the Yas [sic] and Murrumbidgee rivers, and in 1863 he recommended to the Acclimatization Society of N.S.W. that every endeavour should be made to propagate them (Bennett, 1864). Murray cod were held in such high esteem that Dr Gunther considered the species worthy of acclimatization in England (O'Connor, 1897) and Ramel (1868; cited in Berra and Weatherley, 1972) suggested that Murray cod be introduced into Europe. Although this did not eventuate, Murray cod were stocked, during the 19th century into many waters where they were not found naturally. These included the Yarra River, Victoria (Wilson, 1857), the easterly-flowing Cox's, Nepean and Wollondilly rivers on the N.S.W. central coast (Phillips, 1863; Hill, 1864), Mulwarree Ponds near Goulburn and Lake George near Canberra (Macleay *et al.*, 1880), the easterly-flowing Mary river system in southern Queensland (S. H. Midgley, pers. comm.), and the Avon River and Lake Grassmere, Western Australia (Morrissy, 1970). Apart from an occasional specimen captured from the upper reaches of the Yarra River, Murray cod are no longer found at any of these sites. The population of cod in the Mary river system is genetically and morphometrically distinct from *M. peeli*, but its taxonomic status has not been determined (Rowland, 1985).

During the 20th century, Murray cod have been successfully stocked into Lake Bathurst and Lake George in N.S.W. (Whitley, 1937), Lake Charlegrark, Green Lake, Taylor's Lake and the Wimmera River, in the western Wimmera region of Victoria

Fig. 2. The catch aboard the paddlesteamer 'Mayflower' on the Murray River near Renmark, 1911.

(Cadwallader and Backhouse, 1983), Cataract Dam (Anderson, 1916) and several other Sydney water supply dams (Lake, 1959, 1971) and numerous farm dams in the eastern states of Australia.

Murray Cod Fisheries

Development

During the mid to late 1800's a large inland, commercial fishery developed and was based mainly on the Murray and Murrumbidgee rivers (Macleay *et al.*, 1880; Dannevig, 1903; Stead, 1903). Large-scale operators used paddlesteamers as fishing boats (Fig. 2) and set up to 200 drum nets per vessel (Pollard and Scott, 1966). The drum net was introduced into the inland fishery in 1880 (Dannevig, 1903) and has remained the most common method of netting Murray cod and golden perch in the inland rivers and creeks. By 1883 the Murray River fisheries formed a considerable factor in the fish supply to Victoria and during this year more than 147 tons were sent to Melbourne from Moama (Cox, 1884). In 1900 the value of the inland fisheries within the South Australian portion of the Murray River was worth £25,000-£30,000 per annum (Whitley, 1937).

Although few quantitative data are available, it appears that the fishery was based primarily on Murray cod. In 1862 a company of six men and a number of aborigines captured two to three tons of fish per week from the Murray River, south of Deniliquin, which 'abounded with fish, particularly the Murray River cod' and sent them to Bendigo and Melbourne (Jervis, 1952). A professional fisherman from Tailem Bend, South Australia, reported catching '. . . three bags (170 lb each) of Murray cod in one morning' (Stead, 1903). The Fisheries Enquiry Commission of 1879-80 (Macleay *et al.*, 1880) was told by Mr. F. A. Tompson of Wagga, in relation to the fish in the Murrumbidgee River, that 'The cod is the most prominent and remarkable . . . It is brought to market more plentifully than the others . . . a ton of fish is brought in here every week . . . I saw 150 large cod alive in a cart . . . They were sold in two hours or less'.

In 1900, cod accounted for 75% of the river fish available at the Melbourne market, the remainder being golden perch (Poole, 1984). The dominance of Murray cod in professional catches is shown in Fig. 2, the catch aboard the paddlesteamer 'Mayflower' near Renmark in 1911. Dakin and Kesteven (1938) referred to 'the overwhelming importance of cod, the quantity of golden perch and silver perch taken is small compared with quantity of cod'.

Besides the commercial fishery, large numbers of Murray cod were easily caught and used as food by early settlers (Bennett, 1834; Macleay *et al.*, 1880). By 1955 the popularity of inland fishing had increased tremendously and with the aid of motor vehicles, a large recreational fishery had developed (Anon., 1956). During the 1950's large catches of Murray cod could be made by experienced recreational fishermen.

Decline

Dakin and Kesteven (1938) presented the available data on the catch of native fish from the inland waters between 1883 and 1938, and allowing for the limitations as discussed by those authors, the data indicate that although large fluctuations of fish populations occurred in the Murray-Darling river system, there had been a gradual decline in the overall catch from a peak in 1918. By the mid 1930's it was apparent that the commercial fishery had declined to an unprofitable level for the large-scale operators (Whitley, 1937; Pollard and Scott, 1966).

Catch statistics from the commercial fishery in inland N.S.W. between 1940/41 and 1983/84 are presented in Fig. 3. The annual catch of Murray cod increased between

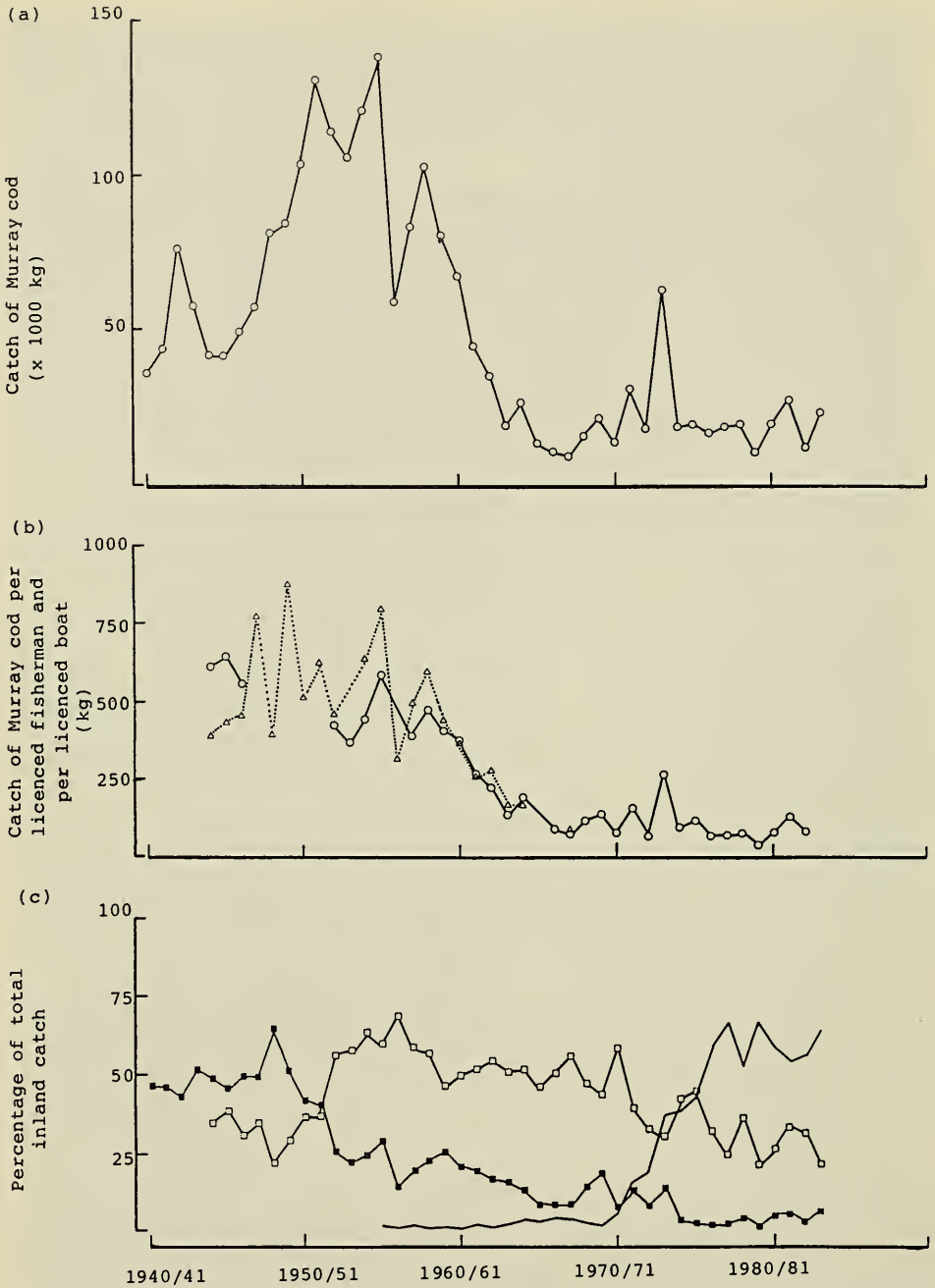

Fig. 3. The total annual catch (a) and catch per licenced fisherman and per licenced boat (b) of Murray cod, and the percentage composition of Murray cod, golden perch and common carp (c) in the commercial catch from inland waters in N.S.W. between 1940/41 and 1983/84 (data from annual reports, N.S.W. State Fisheries).

(b) ○——○ catch per licenced fisherman
△------△ catch per licenced boat

(c) ■——■ Murray cod
□——□ golden perch
—— common carp

1940/41 and 1955/56, but then the total catch and the catch per licenced fisherman declined dramatically (Fig. 3a, b). Murray cod was the major species in the inland fishery until 1951/52, and between 1940 and 1951 cod comprised 42-65% of the total annual catch from inland N.S.W. However, after 1951/52, golden perch (*Macquaria ambigua*) replaced Murray cod as the major native species in the N.S.W. inland fishery (Fig. 3c). The total catch, catch per licenced fisherman and the percentage composition data all strongly suggest that there was a dramatic decline in the abundance of *M. peeli* between 1955 and 1964. There was a concurrent decline in the commercial catch of Murray cod from the Murray River in South Australia (Reynolds, 1976). Between 1940/41 and 1962/63 the annual total catch of Murray cod in N.S.W. exceeded 35,000 kg; however since 1963/64, with the exception of 1974/75, the annual catch has remained below 30,000 kg and the catch per licenced fisherman below 200 kg.

The continued small catch and low catch per licenced fisherman of Murray cod in the N.S.W. commercial fishery since 1960/61 (Fig. 3) indicate that the fishery remains in a depressed state. These catch statistics also indicate that there has been no major reduction or increase in the abundance of Murray cod since the mid 1960's. Consequently, it appears that stocks of Murray cod have remained stable, but at relatively low levels over the last 25 years.

Reduced Distribution

There has also been a reduction in the distribution of *M. peeli*. Many historical reports indicate that the species was common in rivers where cod are now rare or no longer found. The explorer George Evans, the first European man to see the species (Stanbury and Phipps, 1980), observed cod in the Fish River before he reached the present site of Bathurst. The type locality of *M. peeli* is the Peel River, N.S.W. probably near the present site of Tamworth (Mitchell, 1838) and in 1836 an enormous 120 lb 'River codfish of the Colonists' was found entangled and struggling near the bank in a pond of the Cudegong River (Bennett, 1864). Murray cod are now extremely rare in the Fish, Peel and Cudegong rivers.

In Victoria, Murray cod abounded in the Loddon, Campaspe and Goulburn rivers and their tributaries, even where the waters 'dwindled into the most insignificant streams' (Wilson, 1857). By the late 1940's the populations of Murray cod and other native fishes had declined in these rivers (Langtry, in Cadwallader, 1977) and there are now very few localities in Victoria where Murray cod can be considered common (Cadwallader and Backhouse, 1983).

Fisheries Management and Research

Concern about the stocks of Murray cod was expressed as early as the 1880 Royal Commission enquiring into the Fisheries of N.S.W. (Macleay *et al.*, 1880) and from 1883 until about 1895 there was some supervision of inland waters (Dakin and Kesteven, 1938). Dannevig (1903) detailed measures for restricting gear, protecting fry and young fish and the imposition of a closed season. From 1905 to 1910 serious attempts were made to improve the cod fishery, including experiments conducted in 1905 by H. C. Dannevig on the artificial propagation of cod (Farnell, 1906; Dakin and Kesteven, 1938). Whitley (1937) briefly discussed the available information on the distribution, fishery, breeding and taxonomy of Murray cod and included a complete bibliography containing mostly taxonomic references. In 1936, a conference on the Murray River fisheries, attended by representatives from N.S.W., Victoria and South Australia, adopted a closed season of September, October and November for the taking of Murray cod; set minimum legal lengths; suggested that hatcheries be established; asked the Murray River Commission to construct a fishway at Lock 15 at Euston; and suggested

that the breeding habits and migration of freshwater indigenous fishes be studied by each State (Isherwood, 1939).

However, since that time only five studies have contributed significantly to the knowledge of the biology of *M. peeli*. Dakin and Kesteven (1938) presented brief notes on the natural history, behaviour in captivity and the spawning season of Murray cod; they also discussed the cod fishery including the evidence for, and possible causes of the decline of cod stocks. Dakin and Kesteven artifically bred cod by capturing and stripping ripe fish; the eggs, embryonic development, larvae and fry were described. However, this part of the study was restricted by the difficulty of procuring ripe broodfish from the wild. The need for future research into the biology and breeding of this species was emphasized.

J. O. Langtry conducted an ecological survey of the Murray River and some of its tributaries in 1949-50. Unfortunately, his report was not published, and it wasn't until 1977 that the manuscript was rewritten and presented by Cadwallader (1977). The report contains data on the relative abundance of fishes in the study area and describes the differences between Murray cod and trout cod (*Maccullochella macquariensis*). Langtry also made observations and collected some quantitative data on the distribution, diet, breeding biology and growth rate of Murray cod.

During the 1960's, John Lake studied the reproductive biology of native fishes at the Inland Fisheries Research Station, Narrandera, N.S.W. and his research demonstrated that critical temperatures and rising water levels in ponds (and presumably a flood or fresh in the wild) triggered the spawning of some species (Lake, 1967 a,b). Cadwallader and Gooley (1985) collected data on the spawning of Murray cod in earthen ponds, and developed techniques for the artificial propagation and rearing of *M. peeli*. Rowland (1985) conducted research into the biology and artificial breeding of *M. peeli*, and some of his findings form the basis of the following discussion.

Possible Causes of the Decline

Reduced Larval Recruitment

The high survival of fish larvae is dependent on the availability of relatively high concentrations of suitable-sized food organisms at the commencement of exogenous feeding; suboptimal feeding conditions generally result in death due to starvation or predation (May, 1974; Pitcher and Hart, 1982). Hjort (1926) hypothesized that the degree of mortality of larvae during a 'critical period' after the completion of yolk sac absorption determined the strength of year-classes in natural populations. Although the relationship between larval mortality during the 'critical period' and year-class strength is difficult to determine in nature (May, 1974) it is generally thought that the survival rate of fish larvae is the most important factor determining the strength of year-classes (Beverton, 1962; Gulland, 1965; May, 1974; Pitcher and Hart, 1982).

Many overseas studies have shown that strong year-classes of freshwater fishes are established when the breeding season coincides with rising or high water levels (e.g. Aggus and Elliott, 1975; Stevens, 1977; Marshall, 1982; Beam, 1983). Although *M. peeli* spawned annually in the southern tributaries of the Murray-Darling river system between 1977 and 1980, relatively strong year-classes were only established when the breeding seasons coincided with high river levels or floods (Rowland, 1985), demonstrating that floods in October and November provide optimum conditions for the survival and recruitment of *M. peeli* larvae.

The floodplain areas of the Murray-Darling river system are highly productive. When they are inundated in spring or summer, a rich source of terrestrial nutrients, plus the plankton, aquatic insects (in particular chironomid larvae) and other organisms

of the billabongs become available to the aquatic community of the rivers (Frith, 1959; Shiel, 1980; Maher and Carpenter, 1984). Zooplankton, chironomid larvae and other aquatic insects are the major food items of the larvae and fry of Murray cod and golden perch in earthen ponds, and a delay of several days in the availability of food to larvae after the completion of yolk sac absorption results in reduced survival in both species (Rowland, 1985, 1986).

The construction of dams, high-level weirs and levee banks on the major tributaries of the Murray-Darling system has altered the natural flow and temperature regimes and dramatically reduced the frequency, extent and duration of floods (Lake, 1971; Reynolds, 1976; Cadwallader, 1978; Walker *et al.*, 1978; Walker, 1979). The Murray River no longer floods annually in spring and much of the vast anabranch, billabong and floodplain areas of the Murray and Murrumbidgee rivers have been eliminated and do not flood except under extraordinary circumstances (Langtry, in Cadwallader, 1977; Shiel, 1980). Consequently optimum conditions for the survival of the larvae of Murray cod, which usually spawn in October or November, now rarely occur. It is suggested that the reduced frequency, extent and duration of spring flooding in the Murray-Darling river system has led to an overall reduction in larval recruitment and that this is a major cause of the decline in the abundance of *M. peeli*.

This hypothesis is supported by the change in the relative proportion (by weight) of Murray cod and golden perch in the commercial catch from inland N.S.W. (Fig. 3c). Prior to 1951/52, *M. peeli* was the major species; however, since then golden perch have formed a much greater percentage of the annual catch than have Murray cod. Golden perch require a substantial rise in water level, when temperatures are about 23°C, to induce spawning (Lake, 1967a); if suitable conditions do not occur in the wild, adults remain at an advanced stage of gonadal development until March or April (Mackay, 1973). Therefore *M. ambigua* can delay spawning over a six month period whereas *M. peeli* spawns only during spring and early summer when the water temperature is about 20°C (Rowland, 1983, 1985; Cadwallader and Gooley, 1985). The reduced frequency and extent of flooding, in particular the reduction of flooding which usually occurred each spring in the Murray and Murrumbidgee rivers (Langtry, in Cadwallader, 1977; Walker *et al.*, 1978; Walker, 1983) would be expected to affect larval recruitment to a greater extent in *M. peeli* than in *M. ambigua*.

The major impoundments on the Murray-Darling river system in N.S.W. were constructed between 1907 and 1976; Burrinjuck Dam 1907 (enlarged 1957), Hume Dam 1936 (enlarged 1961), Wyangla Dam 1936 (enlarged 1971), Yarrawonga Weir 1939, Keepit Dam 1960, Menindee Lake Storage Scheme 1960, Burrendong Dam 1967, Blowering Dam 1968, Pindari Dam 1969, Copeton Dam 1976 (Anon., undated; Walker, 1980). By 1950, the effects of Hume Dam and Yarrawonga Weir on the flow in the Murray River were clearly evident (Langtry, in Cadwallader, 1977). The cumulative effects of the major impoundments and water storage schemes would have been substantial by 1960 when there was an apparent rapid decline in the abundance of Murray cod.

Overfishing

The relatively large inland commercial fishery which existed between the mid 1800's and the late 1930's and which was based primarily on Murray cod (Macleay *et al.*, 1880; Dannevig, 1903; Stead, 1903; Dakin and Kesteven, 1938) would have placed intense fishing pressure on cod populations. Previously unfished populations of long-lived fishes consisting of 12 or more year-classes are extremely susceptible to exploitation; and with unchanging recruitment the absolute size of the total stock will decline markedly, or even catastrophically under moderate exploitation (Ricker, 1963). It is

therefore probable that the decline in abundance of Murray cod, at least until the 1930's, by which time the inland commercial fishery had become unprofitable for large-scale operators (Pollard and Scott, 1966), was caused primarily by overfishing.

A possible reduction in the exploitation of cod populations after the 1930's due to the depressed state of the fishery, the Depression and World War II, may have resulted in numbers and the catch per licenced fisherman/boat remaining reasonably stable or even increasing (Fig. 3) until the late 1950's when, as suggested, the effects of reduced larval recruitment became apparent by the rapidly declining stocks. It is also possible that the recreational fishery which developed in the 1950's (Anon., 1956; Poole, 1984) contributed to the decline of cod stocks during this period.

English Perch (Redfin)

English perch, *Perca fluviatilis*, were abundant and sympatric with *M. peeli* in the southern tributaries of the Murray-Darling system between the late 1940's and the 1960's. Langtry (in Cadwallader, 1977) found that the diet of *P. fluviatilis* was identical to that of *M. peeli* and *M. ambigua*, and small fishes become a major part of the diet of larger English perch (Lake, 1967c). English perch larvae and juveniles feed on zooplankton, crustaceans and insect larvae, and because *P. fluviatilis* spawns in early spring when temperatures are about 12°C; usually the last week or so in August in southern N.S.W. (Lake, 1967c), juvenile English perch may prey on, and possibly compete for food with Murray cod larvae and fry, particularly during drought periods when food resources are limited. The catch data on fishes from the Kerang Lakes, Victoria, between 1919 and 1949 (Figure 1 in Cadwallader, 1977) demonstrated that when English perch were abundant, native fish were scarce and *vice versa*. It is therefore possible that English perch have contributed to the decline of Murray cod in the southern parts of the Murray-Darling river system.

Other Factors

Factors such as siltation, desnagging, channelization, depressed water temperatures below impoundments, and barriers preventing spawning migrations have been implicated in the decline of native fishes (see Merrick and Schmida, 1984). While some of these factors may be responsible for the decline of some species in certain areas, because of the great size of the Murray-Darling river system it is unlikely that they have been major contributing factors to the decline of *M. peeli* which is widely distributed throughout the system (Lake, 1971) and does not undergo extensive migrations (Reynolds, 1983).

Summary

Historical aspects of Australia's most famous and largest inland freshwater fish, the Murray cod, *Maccullochella peeli*, are briefly reviewed. Fossil records suggest that ancestral Murray cod are of, at least Miocene age. The Murray cod played a prominent part in the mythology and culture of some aboriginal tribes. Explorers, including George Evans, John Oxley, Thomas Mitchell, and Charles Sturt, and the early, inland settlers were astounded by the abundance, size and delicacy of Murray cod. The species was held in such high esteem that it was considered worthy of acclimatization in England and Europe, and although this did not eventuate *M. peeli* was extensively translocated within and outside its natural range of the Murray-Darling river system during both the 19th and 20th centuries.

During the late 1800's a large, inland, commercial fishery developed. It was based on Murray cod and was located mainly on the mid and lower reaches of the Murray and

Murrumbidgee rivers. Historical records and catch statistics indicate that there has been a dramatic decline in the abundance and a reduction in the distribution of *M. peeli*. Possible causes of the decline are briefly discussed. It is suggested that overfishing contributed to a decline between the late 1800's and the 1930's, but that the reduced frequency, extent and duration of spring flooding in the Murray-Darling river system, caused by the construction of dams, high-level weirs and levee banks, has adversely affected larval recruitment in *M. peeli*. This has caused the dramatic decline in abundance of cod during the 1950's and the maintenance of stocks at relatively low levels over the last 25 years.

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